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U.S. PATENT APPLICATION

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Invention: STRUCTURE OF SPARK PLUG DESIGNED TO PROVIDE HIGHER WEAR
RESISTANCE TO CENTER ELECTRODE AND PRODUCTION

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SPECIFICATION

STRUCTURE OF SPARK PLUG DESIGNED TO PROVIDE HIGHER
WEAR RESISTANCE TO CENTER ELECTRODE AND PRODUCTION
METHOD THEREOF

BACKGROUND OF THE INVENTION

5 1 Technical Field of the Invention

The present invention relates generally to a spark plug in
which sparks are produced between a second ground electrode and
a center electrode when a porcelain insulator is stained with carbon,
and more particularly to an improved structure of such a type of
10 spark plug designed to provide higher wear resistance to a center
electrode for increasing the useful life of the spark plug and a
production method thereof.

2 Background Art

European Patent Application EP 1 006 631 A2 discloses a
15 conventional spark plug of a type in which production of electric
sparks is initiated between a second ground electrode and a center
electrode when a porcelain insulator is stained with carbon. Fig. 10
shows a typical structure of such a type of spark plug.

The spark plug includes a porcelain insulator 2 installed
20 within a metal shell (not shown). Within the porcelain insulator 2,
a center electrode 3 is disposed which has a tip 3a projecting from a
tip 2a of the porcelain insulator 2. A noble metal chip 3d is welded
to the tip 3a of the center electrode 3.

The spark plug also includes a first ground electrode 4 and a
25 pair of second ground electrodes 5 (only one is shown for the brevity

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of illustration) which are installed on an end of the metal shell. The first ground electrode 4 is opposed at an end thereof to the noble metal chip 3d of the center electrode 3 to define a spark gap. The second ground electrode 5 has an end facing an end portion of a side surface of the center electrode 3 exposed outside the tip 2a of the porcelain insulator 2.

In operation, electric sparks are generated sequentially between the first ground electrode 4 and the center electrode 3 to ignite a gaseous fuel such as an air-fuel mixture injected into an internal combustion engine. When the fuel is burned, it will cause carbon to stick to the surface of the tip 2a of the porcelain insulator 2, thereby resulting in a decreased degree of electric insulation of the porcelain insulator 2. This causes sparks to be initiated between the second ground electrode 5 and the center electrode 3, thereby burning away the carbon adhered to the porcelain insulator 2. When the surface of the porcelain insulator 2 is cleaned of the carbon, it will cause sparks to be generated again between the first ground electrode 4 and the center electrode 3.

In order to improve the effects of burning the carbon away from the porcelain insulator 2, a shoulder 3b is formed on the center electrode 3 which tapers off to the tip 3a. A boundary 3c between a major portion of the center electrode 3 and the shoulder 3b is located inside the porcelain insulator 2.

The boundary 3c forms a corner on which an electric field is concentrated. Sparks, thus, fly, as indicated by an arrow in the drawing, over the tip 2a of the porcelain insulator 2 between the

boundary 3c and the end of the second ground electrode 5, which serves to burn the carbon away from the porcelain insulator 2 effectively.

Researches carried out by the inventors of this application, however, showed that even though the carbon does not stick to the surface of the porcelain insulator 2, sparks may be produced between the second ground electrode 5 and the center electrode 3 depending upon specifications and/or operating conditions of the engine.

The production of sparks between the second ground electrode 5 and the center electrode 3 when there is no carbon sticking to the porcelain insulator 2 will cause a portion, as indicated by S in the drawing, of the side wall of the center electrode 3 to be worn or scooped away, thus resulting in scattering of metallic components of the center electrode 3 onto the surface of the porcelain insulator 2. When the metallic components are deposited on the porcelain insulator 2, it facilitates ease of production of sparks between the second ground electrode 5 and the center electrode 3, thus increasing the worn of the side wall of the center electrode 3 undesirably.

SUMMARY OF THE INVENTION

It is therefore a principal object of the invention to avoid the disadvantages of the prior art.

It is another object of the invention to provide an improved structure of a spark plug of a type as described above which is

designed to provide a higher wear resistance to a center electrode for increasing the useful life of the spark plug and a fabrication method thereof.

According to one aspect of the invention, there is provided an

5 improved structure of a spark plug which may be employed in automotive engines and is designed to have a higher wear resistance to electrical sparks. The spark plug comprises: (a) a metal housing; (b) a porcelain insulator installed in the metal housing; (c) a center electrode retained within the porcelain insulator, the center

10 electrode having a length and a tip portion projecting from a tip of the porcelain insulator; (d) a shoulder formed on a side wall of the center electrode to define a large-diameter portion and a small-diameter portion of the center electrode, the shoulder tapering off to the tip portion of the center electrode and having a boundary

15 leading to the large-diameter portion located inside the porcelain insulator; (e) a first ground electrode installed on the metal housing which has an end portion opposed to the tip portion of the center electrode to define a first spark gap therebetween; (f) a second ground electrode installed on the metal housing which has an end

20 arranged outside the tip of the porcelain insulator and opposed over the tip of the porcelain insulator to a portion of the side wall of the center electrode to define a second spark gap in which sparks are to be generated to burn away carbon adhered to a surface of the tip of the porcelain insulator, resulting in a decrease in insulation

25 resistance offered by the porcelain insulator; and (g) a wear resisting member provided on the portion of the side wall of the center

electrode for offering resistance to wear caused by the sparks generated in the second spark gap.

In the preferred mode of the invention, if an interval between an inner wall of the porcelain insulator and the side wall of the center electrode is defined as d , and a circle is defined which has a center on an inside corner of the tip of the porcelain insulator facing the center electrode and a radius R defined on a plane including a longitudinal center line of the spark plug, the interval d is preferably the radius R plus 1mm, and the wear resisting member is preferably located at least inside the circle.

The wear resisting member has a width which is opposed to the center electrode and greater than or equal to 0.5mm.

The wear resisting member is provided over an entire periphery of the side wall of the center electrode.

The resisting member may have a surface substantially lying flush with a surface of the side wall of the center electrode.

The wear resisting member is made of a metallic material which is higher in melting point than an Ni alloy. For example, the metallic material may be a Pt alloy or an Ir alloy.

According to the second aspect of the invention, there is provided a method of producing a spark plug including: (a) a metal housing; (b) a porcelain insulator installed in the metal housing; (c) a center electrode which is retained within the porcelain insulator and has a tip portion projecting from a tip of the porcelain insulator; (d) a first ground electrode installed on the metal housing which has an end portion opposed to the tip portion of the center electrode; and (e)

a second ground electrode installed on the metal housing which has an end arranged outside the tip of the porcelain insulator and opposed over the tip of the porcelain insulator to a portion of a side wall of the center electrode. The method comprises the steps of: (a)

5 preparing a center electrode material for making the center electrode; (b) machining the center electrode material to form a large-diameter portion, a small-diameter portion closer than the large-diameter portion to a tip of the center electrode material, and a shoulder between the large-diameter and the small-diameter

10 portions; and (c) welding a wear resisting member to the shoulder of the center electrode material:

In the preferred mode of the invention, the method further comprises the step of machining the center electrode material and the wear resisting member welded to the shoulder of the center

15 electrode material to establish a desired shape of the center electrode.

The method further comprises the step of welding a noble metal chip to a tip of the center electrode.

According to the third aspect of the invention, there is

20 provided a method of producing a spark plug including: (a) a metal housing; (b) a porcelain insulator installed in the metal housing; (c) a center electrode which is retained within the porcelain insulator and has a tip portion projecting from a tip of the porcelain insulator; (d) a first ground electrode installed on the metal housing which has an

25 end portion opposed to the tip portion of the center electrode; and (e) a second ground electrode installed on the metal housing which has

an end arranged outside the tip of the porcelain insulator and
opposed over the tip of the porcelain insulator to a portion of a side
wall of the center electrode. The method comprises the steps of: (a)
preparing a ring-shaped wear resisting member working to provide
5 resistance to spark-caused wear; (b) preparing a center electrode
material for making the center electrode; (c) machining the center
electrode material to form a large-diameter portion, a small-diameter
portion closer than the large-diameter portion to a tip of the center
electrode material, and a shoulder between the large-diameter and
10 the small-diameter portions; and (d) welding the ring-shaped wear
resisting member to the shoulder of the center electrode material:

In the preferred mode of the invention, the method further
comprises the step of machining the center electrode material and
the ring-shaped wear resisting member welded to the shoulder of the
15 center electrode material to establish a desired shape of the center
electrode.

The method further comprises the step of welding a noble
metal chip to a tip of the center electrode.

BRIEF DESCRIPTION OF THE DRAWINGS

20 The present invention will be understood more fully from the
detailed description given hereinbelow and from the accompanying
drawings of the preferred embodiments of the invention, which,
however, should not be taken to limit the invention to the specific
embodiments but are for the purpose of explanation and
25 understanding only.

In the drawings:

Fig. 1 is a partially sectional view which shows a spark plug according to the invention;

Fig. 2 is a partially enlarged view which shows a structure of
5 a tip of the spark plug of Fig. 1;

Fig. 3 is a top view of Fig. 2;

Fig. 4(a) is a partially longitudinal sectional view which shows a desired location of a wear resisting member installed on a center electrode;

10 Fig. 4(b) is a top view of Fig. 4(a);

Figs. 5(a), 5(b), and 5(c) are perspective views which show materials which may be used in forming a wear resisting member;

Figs. 6(a), 6(c), 6(d), and 6(e) are side views which show a sequence of fabrication processes of a wear resisting member using
15 the material of Fig. 5(a);

Fig. 6(b) is a top view of Fig. 6(a);

Figs. 7(a), 7(c), 7(d), and 7(e) are side views which show a sequence of fabrication processes of a wear resisting member using the material of Fig. 5(b);

20 Fig. 7(b) is a top view of Fig. 7(a);

Figs. 8(a), 8(c), and 8(d) are side views which show a sequence of fabrication processes of a wear resisting member using the material of Fig. 5(c);

Fig. 8(b) is a top view of Fig. 8(a);

25 Figs. 9(a) and 9(b) are side views which shows modifications of a wear resisting member; and

Fig. 10 is a partially sectional view which shows a conventional spark plug in which a second ground electrode is opposed to a center electrode for producing sparks useful in burning carbon away from a porcelain insulator.

5 DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings, wherein like reference numbers refer to like parts in several views, particularly to Figs. 1 to 3, there is shown a spark plug 100 which may be used in internal combustion engines for automotive vehicles.

10 The spark plug 100 includes a cylindrical metal housing or shell 1, a porcelain insulator 2, a center electrode 3, a first ground electrode 4, and a pair of second ground electrodes 5 and 6 serving as auxiliary electrodes.

The metal shell 1 is made of a metallic cylinder and has cut
15 therein a thread 1a for mounting the spark plug 100 in an engine block (not shown). The porcelain insulator 2 made of an alumina ceramic (Al_2O_3) is retained within the metal shell 1 and has a tip 2a exposed out of the metal shell 1.

The center electrode 3 is retained in a central chamber 2b of
20 the porcelain insulator 2 and insulated electrically from the metal shell 1. The center electrode 3 has a tip 3a projecting from the tip 2a of the porcelain insulator 2. The center electrode 3 is formed by a cylindrical member which is made up of a core portion made of a metallic material such as Cu having a higher thermal conductivity
25 and an external portion made of a metallic material such as an

Ni-based alloy having higher thermal and corrosion resistances.

The center electrode 3, as clearly shown in Fig. 3, has a shoulder 3b tapering off to the tip 3a thereof. The boundary 3c (will also be referred to as a base of the shoulder 3b below) between the shoulder 3a and a large-diameter portion 3e of the center electrode 3 is located inside the porcelain insulator 2. To an end surface of the tip 3a of the center electrode 3 (i.e., the top of the shoulder 3b), a noble metal chip 3d made of a Pt alloy or an Ir alloy is welded.

The first ground electrode 4 and the second ground electrodes 5 and 6 are, as clearly shown in Figs. 2 and 3, welded to an end of the metal shell 1 and made of Ni-alloy or Fe-alloy poles. In Fig. 2, the porcelain insulator 2 is represented by a sectional view, and a base portion of the first ground electrode 4 connected to the end of the metal shell 1 is omitted for the sake of ease of visibility of the center electrode 3.

The first ground electrode 4 is, as can be seen from Fig. 1, bent inwardly and extends over the noble metal chip 3d installed on the tip 3a of the center electrode 3 to define a spark gap A, as shown in Fig. 2, between a side surface of the end of the first ground electrode 4 and the end of the noble metal chip 3d. In the side surface of the first ground electrode 4 opposed to the noble metal chip 3d, a noble metal chip 4a made of a Pt alloy or an Ir alloy is, as clearly shown in Fig. 2, embedded by welding.

The second ground electrodes 5 and 6 are opposed diametrically to each other and bent to have end surfaces 5a and 6a facing the shoulder 3b of the center electrode 3 beyond the tip 2a of

the porcelain insulator 2 to define second spark gaps in which sparks are to be produced, as already described in the introductory part of this application, between the end surfaces 5a and 6a and the based 3c of the shoulder 3b beyond the tip 2a of the porcelain
5 insulator 2 when the tip 2a of the porcelain insulator 2 is stained with carbon. The end surfaces 5a and 6a of the second ground electrodes 5 and 6 are located outside the tip 2a of the porcelain insulator 2. Only one of the second ground electrodes 5 and 6 may alternatively be installed on the metal shell 1.

10 In operation, a sequence of sparks are produced within the spark gap A or between the noble metal chips 3d and 4d of the center electrode 3 and the first ground electrode 4 to ignite and burn a gaseous fuel injected into the engine. The burning of the fuel will cause carbon to stick to the surface of the tip 2a of the porcelain
15 insulator 2, thereby resulting in initiation of sparks between the second ground electrodes 5 and 6 and the center electrode 3 for the reasons as described in the introductory part of this application. The sparks are produced between each of the second ground electrodes 5 and 6 and an area of the side surface of the center
20 electrode 3 which includes the base 3c of the shoulder 3 and faces the tip 2a of the porcelain insulator 2 and fly along the surface of the tip 2a of the porcelain insulator 2, thereby burning the carbon away from the surface of the porcelain insulator 2. When the carbon is burned out, so that the surface of the porcelain insulator 2 is
25 cleaned of the carbon, it will cause sparks to be created between the first ground electrode 4 and the center electrode 3 again.

In order to minimize the wear of the center electrode 3 caused by the sparks produced within the second spark gaps, wear resisting members 7, as indicated by hatching in Fig. 2, are installed at least in portions of the side wall of the center electrode 3 which are
 5 opposed to the second ground electrodes 5 and 6 through the second spark gaps.

Figs. 4(a) and 4(b) are enlarged views of Figs. 2 and 3, respectively, which illustrate one of the wear resisting members 7. Note that Fig. 4(a) is reverse to Fig. 2 in a vertical direction, and the
 10 noble metal chip 3d is omitted for ease of visibility.

Each of the wear resisting members 7 is made of a metallic material which is higher in melting point than an Ni alloy that is material of the outside portion of the center electrode 3. For instance, each of the wear resisting members 7 may be made of a Pt
 15 alloy or an Ir alloy having a melting point of 1500°C or more.

In Fig. 4(a), d indicates the interval between the inner surface of the tip 2a of the porcelain insulator 2 and the side surface of the center electrode 3. K indicates a circle which has the center defined on the inside corner 2c of the tip 2a of the porcelain insulator 2 and the radius R defined on a plane including a longitudinal center line
 20 of the spark plug 100. Each of the wear resisting members 7 is preferably located inside the circle K . The radius R is preferably greater than or equal to the interval d plus 0.1mm (i.e., $R \geq d + 0.1\text{mm}$).

25 Further, the width L , as shown in Fig. 4(b), of the wear resisting members 7 or the distance between sides of each of the

wear resisting members 7 opposed in a widthwise direction of the second ground electrodes 5 and 6 is preferably greater than or equal to 0.5mm. The wear resisting members 7 may alternatively be formed in the entire peripheral surface of the center electrode 3.

5 As an example, the interval C , as shown in Fig. 4(a), between the base 3c of the shoulder 3b of the center electrode 3 and the end of the tip 2a of the porcelain insulator 2 is 0.25mm. The interval d is 0.05mm. The diameter F , as shown in Fig. 4(b), of the large-diameter portion of the center electrode 3 is 2.3mm. The
10 width G of the second ground electrodes 5 and 6 is 2.2mm. In this example, the radius R of the circle K is 0.35mm. The distance H of the wear resisting members 7 in the lengthwise direction of the spark plug 100 is 0.3mm. Of the distance H , the distance $h1$ between the base 3c of the shoulder 3b of the center electrode 3 and
15 a lower end of the wear resisting members 7 leading to the large-diameter portion of the center electrode 3 is 0.05mm. The distance $h2$ between the base 3c of the shoulder 3b and an upper end of the wear resisting members 7 lying on the shoulder 3b is 0.25mm. The distance or depth T of the wear resisting members 7
20 in a radius direction of the spark plug 100 is 0.3mm. The width L of the wear resisting members 7 is 1.0mm.

Production process of the spark plug 100, especially formation of the wear resisting members 7 on the center electrode 3 will be described below in detail. Others are well known in the art,
25 and explanation thereof in detail will be omitted here.

The wear resisting members 7 may be formed by either of a

pair of Pt alloy bars, a pair of Pt alloy discs, and a single Pt alloy ring, as shown in Figs. 5(a), 5(b), and 5(c), respectively. Figs. 5(a) and 5(b) each show only one for the brevity of illustration. The Pt alloy bars each have a length $m1$ of 1.0mm and a diameter $m2$ of 0.4mm.

5 The Pt alloy discs each have a diameter $p1$ of 1.0mm and a thickness $p2$ of 0.4mm. The Pt alloy ring has an outer diameter $r1$ of 2.4mm and a sectional diameter $r2$ of 0.4mm. In a case of the Pt alloy ring, the single wear resisting member 7 is, as apparent from the discussion below, provided around the periphery of the center
10 electrode 3.

Fabrication processes of the Pt alloy bar of Fig. 5(a) are shown in Figs. 6(a) to 6(e). Fabrication processes of the Pt alloy disc of Fig. 5(b) are shown in Figs. 7(a) to 7(e). Fabrication processes of the Pt alloy ring of Fig. 5(c) are shown in Figs. 8(a) to 8(d).

15 First, the fabrication processes of the Pt alloy bar of Fig. 5(a) will be described below.

The center electrode 3 is first machined to form, as shown in Figs. 6(a) and 6(b), a small-diameter portion at an end thereof. The small-diameter portion is cut or ground to form opposed flat
20 surfaces 10. For example, the interval $n1$ between the flat surfaces 10 is 2.0mm. The length $n2$ of the small-diameter portion of the center electrode 3 is 1.2mm.

Next, the two Pt alloy bars are, as shown in Fig. 6(c), placed on the flat surfaces 10 in parallel to each other in contact with the
25 shoulder 15 and resistance-welded to the flat surfaces 10.

After the Pt alloy bars are welded, the end portion of the

center electrode 3 is machined or ground, as shown in Fig. 6(d), to form the small-diameter portion 3e, the shoulder 3b, and the tip 3a and also finish the Pt alloy bars to a desired shape of the wear resisting members 7, as described above.

5 Finally, the noble metal chip 3d made of an Ir alloy or a Pt alloy is, as shown in Fig. 6(e), joined to the tip 3a of the center electrode 3 by laser-welding or resistance-welding. The center electrode 3 is inserted into the porcelain insulator 2 and secured in place using a glass material.

10 Next, the fabrication processes of the Pt alloy discs of Fig. 5(b) will be described below.

 The center electrode 3 is, like the installation process of the Pt alloy bars, machined to form, as shown in Figs. 7(a) and 7(b), a small-diameter portion at an end thereof. The small-diameter
15 portion is cut or ground to form opposed flat surfaces 10. For example, the interval $q1$ between the flat surfaces 10 is 2.0mm. The length $q2$ of the small-diameter portion of the center electrode 3 is 1.5mm.

 Next, the two Pt alloy discs are, as shown in Fig. 7(c), placed
20 upright on the flat surfaces 10 in contact with the shoulder 15 so that major surfaces of the Pt alloy discs may be opposed in parallel to each other and resistance-welded to the flat surfaces 10.

 After the Pt alloy discs are welded, the end portion of the center electrode 3 is machined or ground, as shown in Fig. 7(d), to
25 form the small-diameter portion 3e, the shoulder 3b, and the tip 3a and also finish the Pt alloy discs to a desired shape of the wear

resisting members 7, as described above.

Finally, the noble metal chip 3d made of an Ir alloy or a Pt alloy is, as shown in Fig. 7(e), joined to the tip 3a of the center electrode 3 by laser-welding or resistance-welding. The center electrode 3 is inserted into the porcelain insulator 2 and secured in place using a glass material.

The fabrication processes of the Pt alloy ring of Fig. 5(c) will be described below.

The center electrode 3 is, as shown in Fig. 8(a), machined to form a circular end with an annular shoulder 17 and the tip 3a.

Next, the Pt alloy ring is, as shown in Fig. 8(c), fitted on the annular shoulder 17. The noble metal chip 3d is placed on the tip 3a of the center electrode 3.

Finally, the Pt alloy ring and the noble metal chip 3d are, as shown in Fig. 8(d), laser-welded to the center electrode 3 to form the wear resisting member 7 around almost the entire periphery of the end of the center electrode 3. The wear resisting member 7 leads to the shoulder 3b (tapered surface in this case) of the center electrode 3. The Pt alloy ring may be configured so as to form the wear resisting member 7 around the entire periphery of the end of the center electrode 3. In this example, the base 3c of the tapered surface 3b lies flush with the surface of the wear resisting member 7. After the process of Fig. 8(d), the end of the center electrode 3 and the wear resisting member 7 may be machined or ground to a desired shape. Finally, the center electrode 3 is inserted into the porcelain insulator 2 and secured in place using a glass material.

The use of the Pt alloy ring permits the wear resisting member 7 to be formed around the entire periphery of the end of the center electrode 3 so that the second ground electrodes 5 and 6 may face the wear resisting member 7 necessarily, thus eliminating the need for positioning the center electrode 3 relative to the porcelain insulator 2 when the center electrode 3 is secured to the porcelain insulator 2.

The noble metal chip 3d installed on the tip 3a of the center electrode 3 in order to improve the wear resistance thereof may be omitted.

As already discussed, each of the wear resisting members 7 is located inside the circle K , as shown in Fig. 4(a), which has the radius R preferably greater than or equal to the interval d plus 0.1mm (i.e., $R \geq d + 0.1\text{mm}$). Researches carried out by the inventor of this application showed that the installation of the wear resisting members 7 inside the circle K ensures a desired degree of resistance to the wear of the side surface of the center electrode 3 over a travel distance of 100000 to 20000 km in an automotive vehicle on which a gasoline engine is mounted.

The width L , as shown in Fig. 4(b), of the wear resisting members 7 is, as described above, preferably greater than or equal to 0.5mm. This alleviates the problem that sparks produced between the side surface of the center electrode 3 and the second ground electrodes 5 and 6 cause portions of the side surface of the center electrode 3 around the wear resisting members 4 to be worn greatly and scooped away in a case where the width L is less than

0.5mm, so that sparks hardly fly to the scooped portions, thereby resulting in concentration of sparks on the wear resisting members 7 which may cause the porcelain insulator 2 to be removed partly, thereby forming an unwanted groove(s).

5 Figs. 9(a) and 9(b) show examples where the single wear resisting member 7 is formed around the entire periphery of the end of the center electrode 3. In either case, the wear resisting member 7 face the second ground electrodes 5 and 6. Specifically, the wear resisting member is formed at least in a portion of the side wall of the
10 center electrode 3 which defines a second spark gap within which sparks are initiated when carbon is deposited on the tip of the porcelain insulator 2.

While the present invention has been disclosed in terms of the preferred embodiments in order to facilitate better
15 understanding thereof, it should be appreciated that the invention can be embodied in various ways without departing from the principle of the invention. Therefore, the invention should be understood to include all possible embodiments and modifications to the shown embodiments which can be embodied without
20 departing from the principle of the invention as set forth in the appended claims.